School of Sustainability
Arizona State University

The Solar Duck Curve and Sustainable Storage Options: A Policy Recommendation

April 27, 2018

Devon Rood

Introduction

Renewable energy is fundamentally different than other sources of power. This is because the most common forms of renewable energy, specifically wind and solar, are dependent on real-time natural processes to produce energy. Solar only produces energy when the sun is shining and produces energy at the height of the day, which is precisely when the utility company does not need extra electricity generation. This mismatch in energy production and energy demand as it applies to solar is referred to as the solar duck curve. At low levels of solar penetration, the extra energy produced by solar during the middle of the day is not a problem. However, as solar has become more accessible to more people, solar is beginning to impact the electric grid in places with high levels of distributed solar.

Arizona Public Service (APS) is the largest electricity provider in Arizona and has a large distributed solar generation portfolio. In fact, APS has over 70,000 customers within its service territory who have solar systems on their homes. With this large distributed solar asset, APS is becoming increasingly worried about the duck curve and how this impacts their other powerplants, especially baseload powerplants like Palo Verde, the largest nuclear powerplant in the U.S. If Palo Verde were forced to close due to the overgeneration from solar in the middle of the day, carbon emissions in Arizona would likely increase due to natural gas peaker plants taking the place of Palo Verde, a zero-carbon generation source.

To maximize the benefits of renewables, APS is interested in gathering more information on three proven energy storage technologies. For this project, pumped hydro energy storage (PHES), compressed air energy storage (CAES), and lithium-ion batteries (Li-ion batteries) were compared to find the option that is the most sustainable based on an analysis of the impacts, both positive and negative, to the environment and communities in addition to the different cost implications for each option. Using a sustainability matrix based on information from academic literature and interviews with professionals, the outcome of this project was a policy recommendation to APS regarding the best storage option.

Methods

A literature review of all three storage technologies was used to gather a significant understanding of the options. This literature review provided a general explanation of the technology, a short history, the benefits, and the difficulties of the three storage technologies explored in this project. In addition to a literature review, meetings with professionals and academics provided a more comprehensive understanding of these storage technologies.

Finally, the experience and knowledge regarding sustainability concepts gained through the coursework for the Master of Sustainable Solutions program were used to create a comparative sustainability matrix that would assess the sustainability of the storage options. The literature review also helped influence the sustainability matrix as the academic research into these storage options outlined the benefits and consequences of these technologies.

This sustainability matrix considers the impacts of PHES, CAES, and Li-ion batteries and evaluate which ones will be best for APS, customers of APS, and the environment. Instead of a typical cost-benefit analysis, the storage options will be evaluated through the lens of sustainability. The impacts on the environment, costs, and communities will be examined as they apply to the storage options. For environmental impacts, the project will examine the carbon emissions, impact on the surrounding environment, and the materials needed. The cost analysis will look at the estimated construction/maintenance costs, lifetime, and reliability. Finally, the impacts on communities will be determined by the potential for displacement, change to the natural area, and the need for new transmission lines. The information provided in this matrix will then be used to determine what would best serve APS and its customers.

Outcomes

While some may think that choosing one energy storage option is simple, the best option is not always apparent from a sustainability point of view. Using the sustainability matrix, CAES was determined to be the most sustainable storage option for APS under current conditions since it has the smallest impact on the environment, is moderate in terms of cost, and has modest impacts on communities. CAES also has the capability to be large in scale and can store energy for long periods of time. Thus, it is a potential option for seasonal storage, something APS wants to explore. This recommendation was surprising considering that CAES requires some use of fossil fuels to operate. The serious negative impacts to the riparian ecosystem and the disruption to communities through the construction of a PHES system gave PHES a lower sustainability score even though PHES is a zero-carbon source of energy storage. Li-ion batteries had similar scores in the matrix as CAES due to its moderate impact on the environment due to its flexibility and its reasonable costs. However, these batteries are not well-suited for seasonal storage as they are generally not as large as CAES or PHES nor do they operate in the same capacity as CAES or PHES.

It is important to note that CAES is not a perfect option. Its high cost as well as some carbon emissions impact the sustainability analysis of this technology. However, many of the characteristics of CAES made it more sustainable than the other options. The use of CAES would help APS use its renewable energy assets more effectively and could help APS keep its zero-carbon resources, like Palo Verde, part of their generation portfolio.

Next Steps

There are many opportunities to expand upon this project. For example, a student can look at other innovative storage options, like desalination or electrolysis, to assess the sustainability of these new storage ideas. Also, a future student can evaluate the sustainability of the recent proposal put forth by Andy Tobin, a member of the Arizona Corporation Commission, calling for Arizona to have 3,000MW of energy storage by 2030 and 80% clean energy by 2050. There are also opportunities for APS to continue the work on this project. APS can start evaluating the possible CAES sites within their territory to see if they are truly suitable for

CAES. Additionally, APS can work more closely with other utilities on the western grid to create a more regional plan to deal with the problem of the solar duck curve.